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SPECTRAL OBSERVATIONS OF FAINT MARKARIAN GALAXIES OF THE SECOND BYURAKAN SURVEY. II.

L. Carrasco[1] and H.M. Tovmassian
Instituto Nacional de Astrofísica Optica y Electrónica, Apartado Postal 51 y 216. C.P. 72000 Puebla, Pue., México
Electronic mail: carrasco@inaoep.mx, hrant@inaoep.mx

J.A. Stepanian
Special Astrophysical Observatory RAS Nizhnij Arkhys, Karachai-Cherkessia, 357147 Russia
Electronic mail: jstep@sao.ru

V.H. Chavushyan[2] and L.K. Erastova[3]
Byurakan Astrophysical Observatory, Byurakan, 378433 Armenia
Electronic mail: chavush@sao.ru and lke@sao.ru

J.R. Valdés
Instituto Nacional de Astrofísica Optica y Electrónica, Apartado Postal 51 y 216. C.P. 72000 Puebla, Pue., México
Electronic mail: jvaldes@inaoep.mx

ABSTRACT

We continue the program of spectroscopic observations of objects from the Second Byurakan Survey (SBS). This survey contains more than 1300 galaxies and 1700 star-like objects with $m_{pg} < 19\overset{m}{.}5$. Our work is aimed towards the construction of a complete sample of faint Markarian galaxies. Here, we present spectroscopic data for 43 galaxies. Amongst them six new Seyfert galaxies are found, namely two Sy 1 type (SBS 1343+544 and SBS 1433+500), one Sy 2 type (SBS 1620+545) and three likely Sy 2 type galaxies (SBS 1205+556,

[1]Also Instituto de Astronomia, UNAM, Ensenada, México

[2]Also Special Astrophysical Observatory RAS, Russia

[3]Visiting Astronomer at the Special Astrophysical Observatory RAS, Russia

SBS 1344+527, SBS 1436+597). SBS 1343+544 falls into the luminosity gap between low-redshift QSOs and high luminosity Sefert galaxies. In the sample studied here, another 36 emission-line galaxies were spectroscopically confirmed. Thus far, 102 SBS galaxies brighter than $17.^{m}5$ have been observed with the Cananea 2.1m GHO telescope.

The apparent magnitude and redshift distributions, the spectral classification, the relative intensities of emission lines, and other parameters, as well as slit spectra for all 43 observed galaxies are presented.

1. INTRODUCTION

In order to built a complete sample of Markarian galaxies up to $m_{pg} < 17^{m}$ contained in the Second Byurakan Survey sample (Markarian & Stepanian 1983, 1984a, b; Markarian, Stepanian & Erastova 1985, 1986; Stepanian, Lipovetsky & Erastova 1988, 1990, Stepanian 1994), a follow-up spectral study of the selected objects is required. Our work is aimed toward this goal.

While high resolution spectral observations of faint objects are being carried out, primarily with the 6 m telescope at SAO in Russia (Stepanian *et al.* 1993 and references therein), observations of relatively brighter objects are carried out with 2.1 m GHO telescope in México. So far, hundreds of QSOs, Seyfert galaxies, Emission Line Galaxies (ELGs), Blue Compact Dwarf Galaxies (BCDGs), as well as some peculiar stars have already been found in the SBS sample.

This long term project shall allow us to compile the first complete sample of faint ($m_{pg} < 17^{m}$) Seyfert and AGN galaxies. Such sample, shall also allow us to construct the Luminosity Function of AGN and UVX galaxies out to a distance of about 500 Mpc.

In a previous paper (Carrasco *et al.* 1997, Paper I) the results of the follow-up spectroscopy of 59 SBS galaxies were presented. In that subsample, five new Seyfert galaxies were found and 51 emission line galaxies were confirmed.

In the present paper we report on the results of the follow-up spectroscopic observations of another 43 relatively bright galaxies ($15.^{m}0 - 17.^{m}5$) from the SBS sample. These observations make part of an ongoing effort to obtain the data required by the scientific goals outlined above. There is also a general interest in increasing the sample of known Seyfert and AGN galaxies.

2. OBSERVATIONS

For our project, two observing runs in March and April 1997 were allocated at Guillermo Haro Observatory of INAOE in Cananea, México. Observations were carried out with the 2.1 m telescope and the LFOSC spectrophotometer equipped with a 600×400 pixel CCD. A set up covering the spectral range of 4000-7100Å was adopted. The effective instrumental spectral resolution was about 11Å.

The journal of observations is presented in Table 1. In consecutive columns the following data are listed: 1 – the SBS designation (1950.0 epoch) 2-3 – the 2000.0 epoch coordinates as measured by Stepanian *et al.* (in preparation). These are accurate to about ± 1 arcsec, 4 – an eye estimated m_{pg} magnitude with an accuracy of about $\pm 0\overset{m}{.}5$, 5 – the SBS spectral class, 6 –the date of observation, 7 – the exposure time, 8 – an alternative designation of the object when available.

3. DATA REDUCTION AND RESULTS

The usual data reduction procedures – cosmic ray hits removal, bias and flat field corrections, wavelength linearization and flux calibration – were carried out with the IRAF reduction package for observations, carried out in March, 1997. While observations carried out in April, 1997 were reduced with software packages developed at the Special Astrophysical Observatory, Russia (Vlasyuk 1993).

The integrated emission line fluxes were determined with the help of the spectral analysis software package developed by Vlasyuk (private communication) at the Special Astrophysical Observatory. This software determines the best-fit Gaussian profile for every line and is capable of deblending closely spaced lines, as is the case of H_α 6563 Å and the $[NII]$ 6548, 6583 Å lines. In our case, this blending is due to the combined effects of the spectral resolution of the spectrometer and the intrinsic width of the emission lines of the objects.

For every galaxy in our sample, the value of the dust reddening coefficient $c(H_\beta)$ was determined from the observed ratio of $I(H_\alpha)/I(H_\beta)$, assuming that the intrinsic ratio of $F(H_\alpha)/F(H_\beta)$ is given by:

$$F(H_\alpha)/F(H_\beta) = I(H_\alpha)/I(H_\beta) \times 10^{c(H\beta)f(\lambda)}$$

where $f(\lambda)$ is listed by Kaler (1976) for a standard galactic reddening law (Whitford 1958).

The values of $c(H_\beta)$ were computed by assuming that the intrinsic ratio of $F(H_\alpha)/F(H_\beta) = 2.85$ for narrow line emission galaxies, and is equal to 3.1 for Sy 2's, and for narrow line components of Sy 1.5 (Veilleux & Osterbrock, 1987).

The results of spectral observations are presented in Table 2, in which the following data are given:

1 – The SBS designation.

2 – The emission line redshift, derived as mean value of redshifts of strong emission lines, corrected for solar motion:

$$\Delta z = 0.001 \sin l^{II} \cos b^{II}$$

3 – The absolute magnitude M_{pg} given by the expression:

$$M_{pg} = m_{pg} - 5\log(z) - 43.01 - 0.24\ cosec\ b^{II}$$

for $H_0 = 75\ km\ s^{-1}\ Mpc^{-1}$.

4 – The reddening coefficient $c(H_\beta)$.

5 – The (H_β) - equivalent width $EW(H_\beta)$.

6-10 – The logarithms of the observed and reddening corrected relative intensities, normalized to H_β or to H_α when H_β is absent. The uncertainty in intensity ratios for strong emission lines reported here is less than 30%.

11 – Spectral type. The Seyfert type, when marked ":" refers to an ambiguous spectral classification.

In the sample studied here, two Seyfert 1 type galaxies – SBS 1343+544 and SBS 1433+500 – were found. The spectrum of SBS 1343+544 shows broad hydrogen emission lines, H_β ($FWHM \sim 8000$ km/s) and H_γ ($FWHM \sim 7000$ km/s). While in the spectrum of SBS 1433+500 the broad emission line $FWHM\ H_\beta \sim 5000$ km/s is evident. In both cases there is narrow [O III] emission.

SBS 1620+545 – has a spectrum typical of Seyfert 2 type galaxies. Three other objects, SBS 1205+556, SBS 1344+527 and SBS 1436+597, most likely are also Seyfert 2 type galaxies.

Mkn 1488 (SBS 1359+521C), presents in its spectrum only the $MgIb$ and NaD absorption lines.

The magnitude and redshift distributions of the entire sample of SBS galaxies and those of the subsample observed in Cananea (including data from Paper I), are presented

in Figures 1 and 2 respectively.

The diagnostic classification diagrams based on emission line ratios (Veilleux and Osterbrock 1987) for the studied objects, including the objects reported in Paper I, are presented in Figures 3(a) and 3(b).

Plots of the spectra of the observed objects are presented in Figures 4 through 6.

4. CONCLUSIONS

The results of the spectrophotometric observations of 43 SBS galaxies made with the Cananea 2.1 m telescope in March 1997 and April 1997 are presented.

Among the objects observed, three new Seyfert galaxies were found. These are two Seyfert 1 type galaxies, SBS 1343+544 and SBS 1433+500, one Seyfert 2 type galaxy, SBS 1620+545. Another three galaxies – SBS 1205+556, SBS 1344+527, and 1436+597 – are probably also Seyfert 2 type objects. In total 42 emission-line galaxies, and one absorption line galaxy were spectroscopically confirmed.

SBS 1343+544 falls in the gap between low-redshift QSOs and higher luminosity Seyfert galaxies, probably meaning that it is a transition object.

Spectral classification, redshifts, relative intensities of the prominent emission lines, as well as other parameters were determined for all 42 emission line galaxies.

5. ACKNOWLEGEMENTS

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Figure Captions

Fig. 1.— The histograms of the stellar magnitude distributions of the whole SBS sample and of the galaxies observed in Cananea.

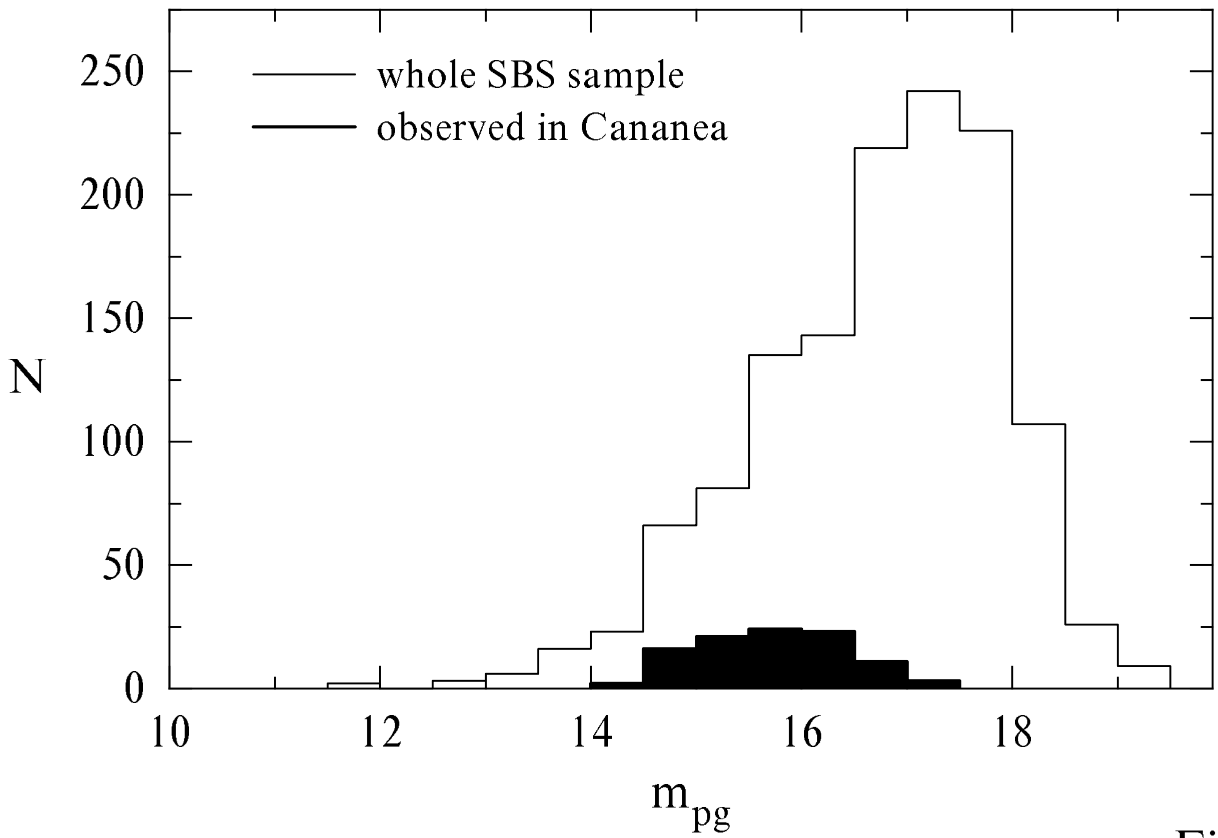
Fig. 2.— The histograms of the redshift distributions of the SBS sample with available spectroscopic data and of the galaxies observed in Cananea.

Fig. 3.— Emission line ratio classification diagrams. The solid line marks the boundary between "HII-region-like" galaxies and AGNs.

Fig. 4.— Plots of the spectra of the observed galaxies in relative flux units. Wavelengths in Angstroms.

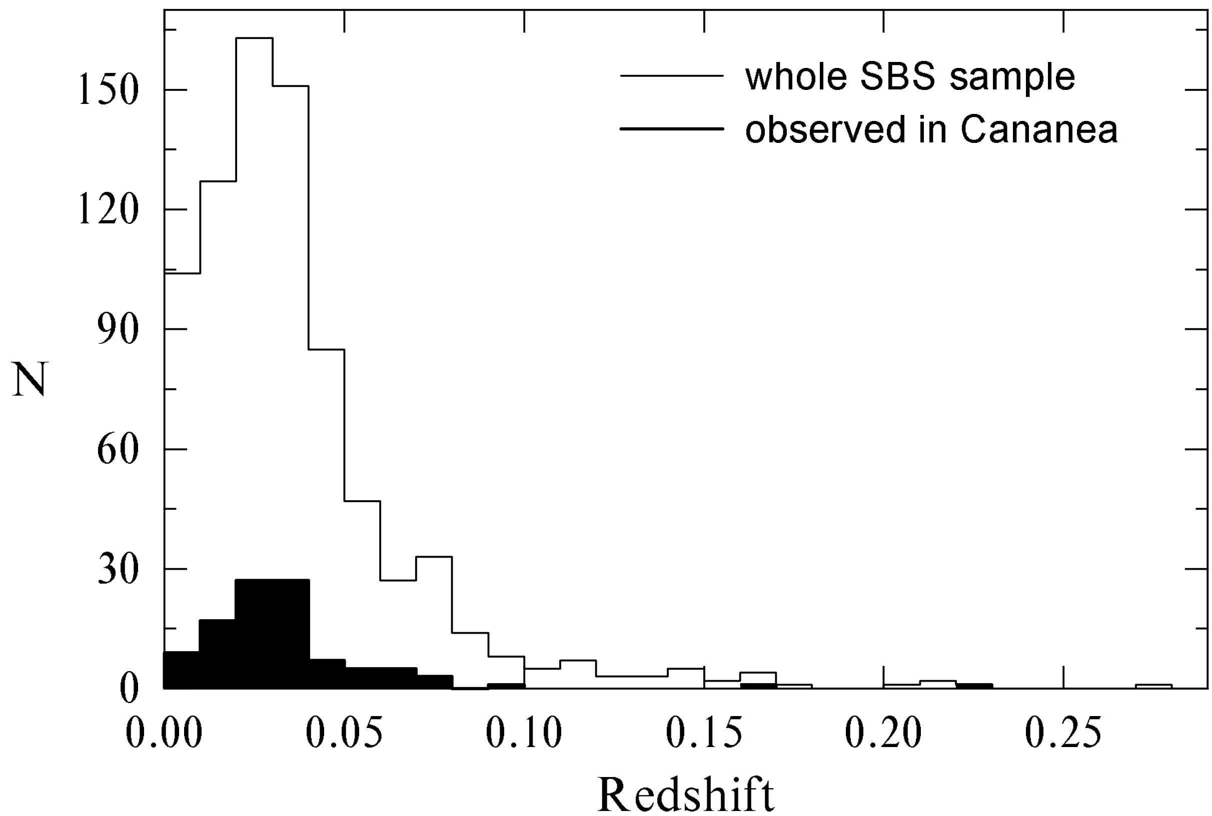
Fig. 5.— Plots of the spectra of the observed galaxies in relative flux units. Wavelengths in Angstroms.

Fig. 6.— Plots of the spectra of the observed galaxies in relative flux units. Wavelengths in Angstroms.



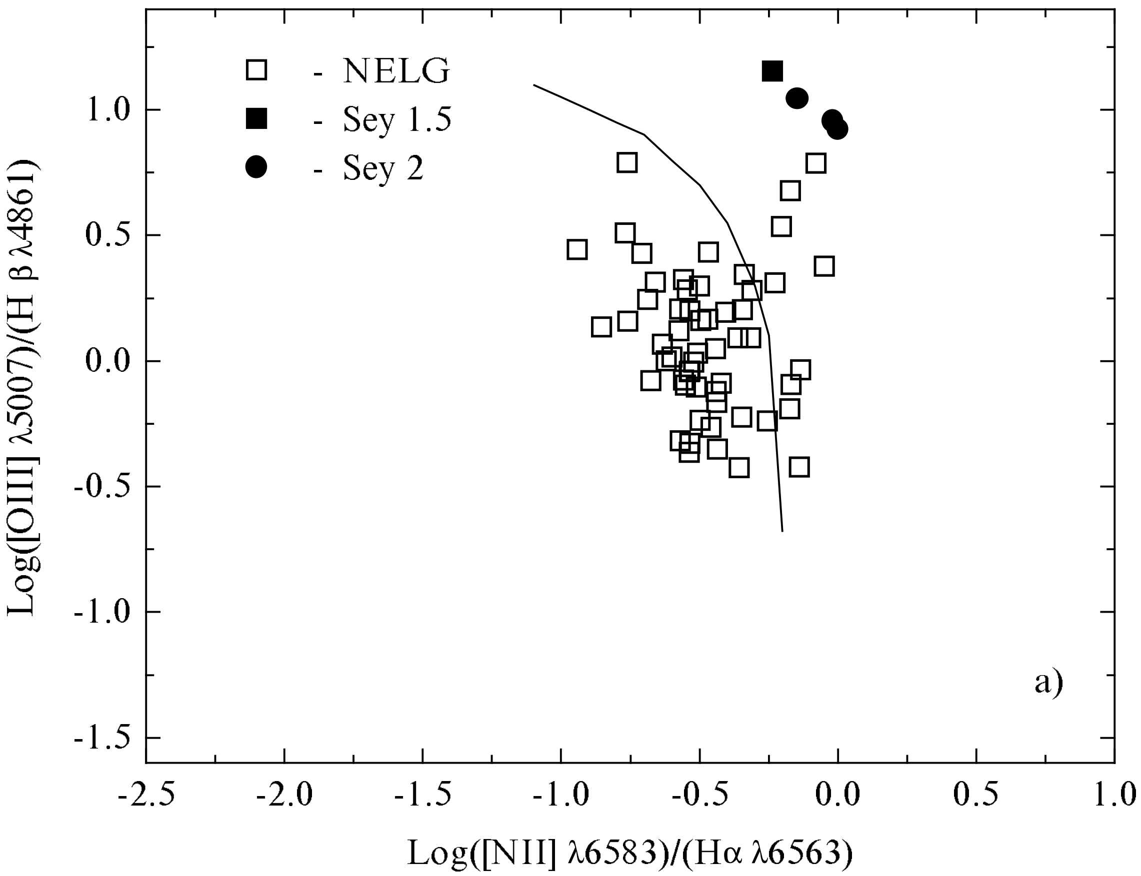
whole SBS sample
observed in Cananea
N
250
200
150
100
50
0
10
12
14
16
18
m_{pg}

Fig. 1.

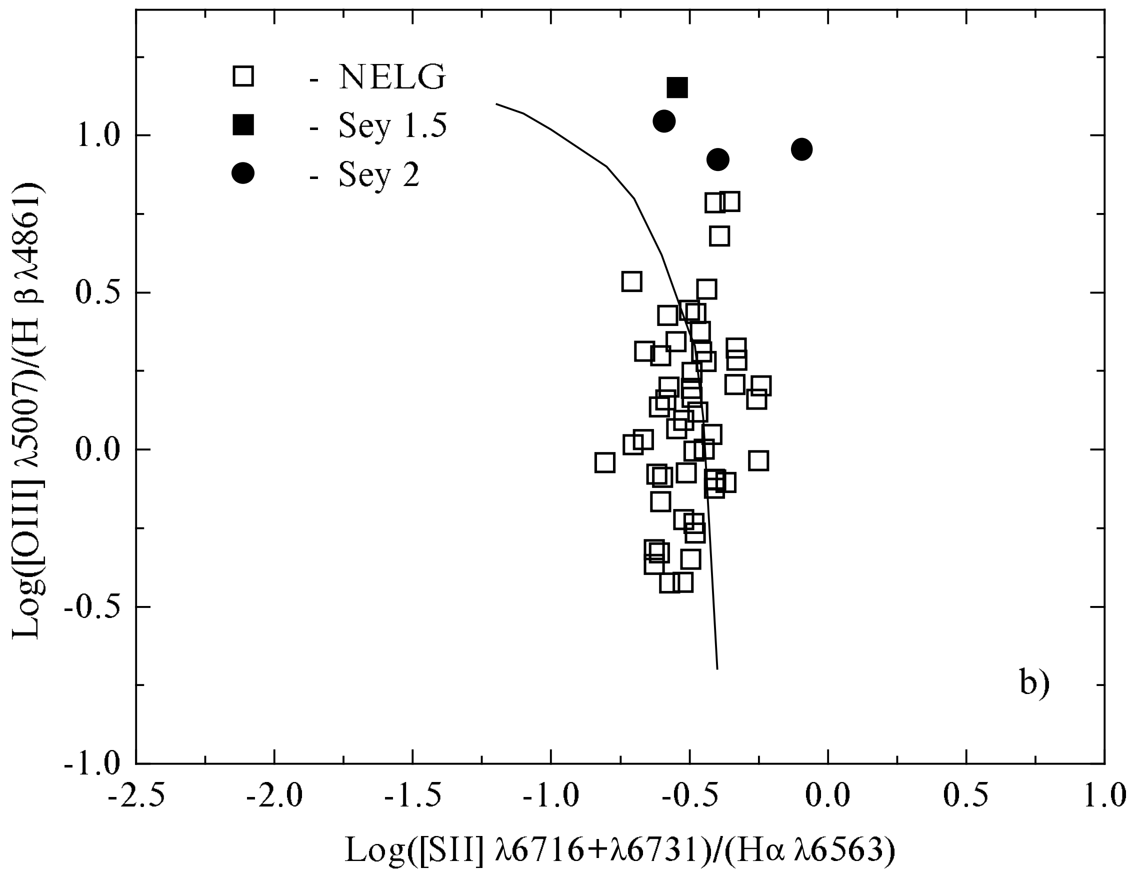


whole SBS sample
observed in Cananea
N
150
120
90
60
30
0
0.00
0.05
0.10
0.15
0.20
0.25
Redshift

Fig. 2.



- NELG
- Sey 1.5
- Sey 2
a)
Log([OIII] λ5007)/(H β λ4861)
Log([NII] λ6583)/(Hα λ6563)



- NELG
- Sey 1.5
- Sey 2
b)
Log([OIII] λ5007)/(H β λ4861)
Log([SII] λ6716+λ6731)/(Hα λ6563)

Fig. 3.

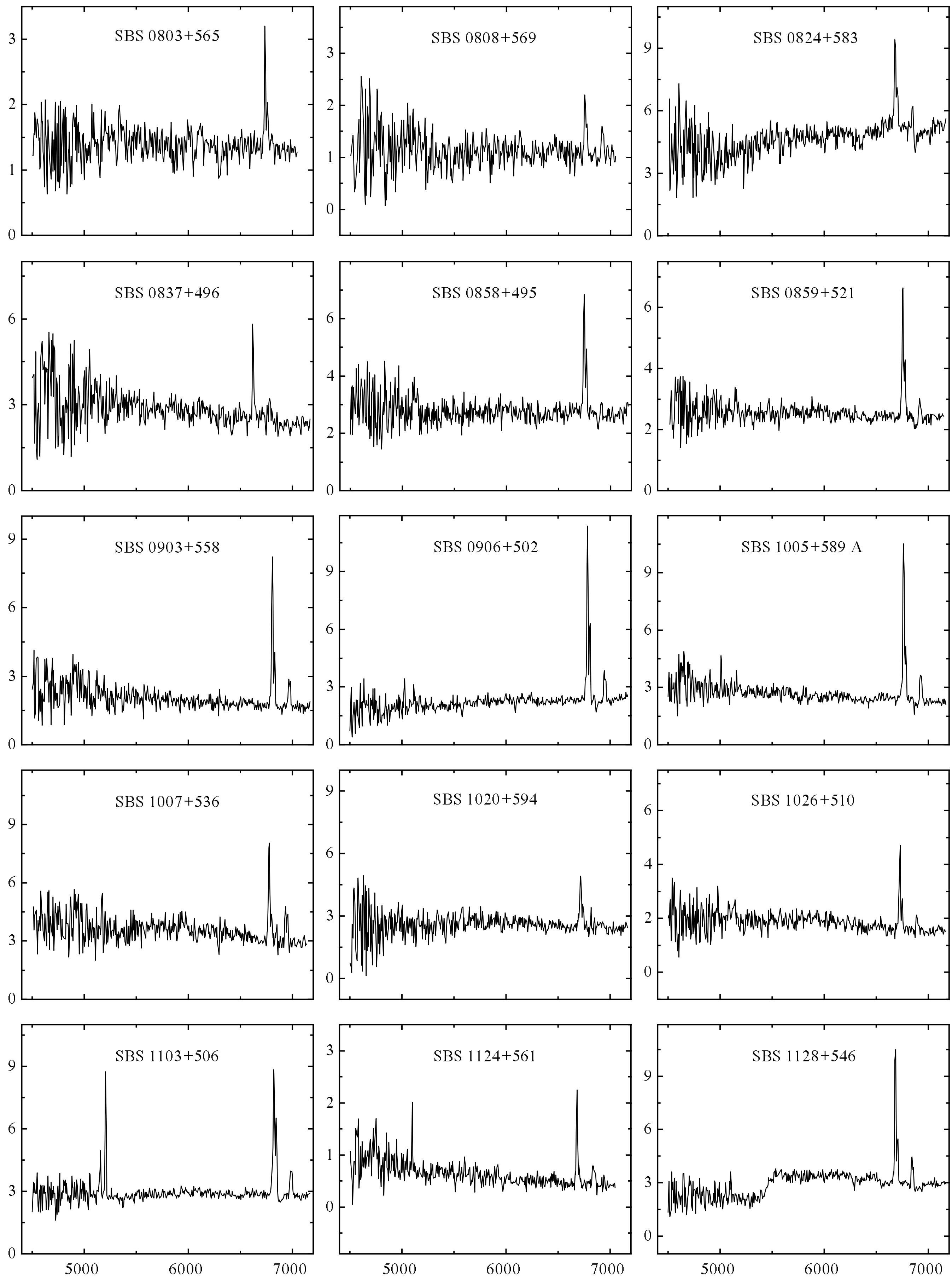

SBS 0803+565
SBS 0808+569
SBS 0824+583
SBS 0837+496
SBS 0858+495
SBS 0859+521
SBS 0903+558
SBS 0906+502
SBS 1005+589 A
SBS 1007+536
SBS 1020+594
SBS 1026+510
SBS 1103+506
SBS 1124+561
SBS 1128+546
5000
6000
7000

Fig. 4.

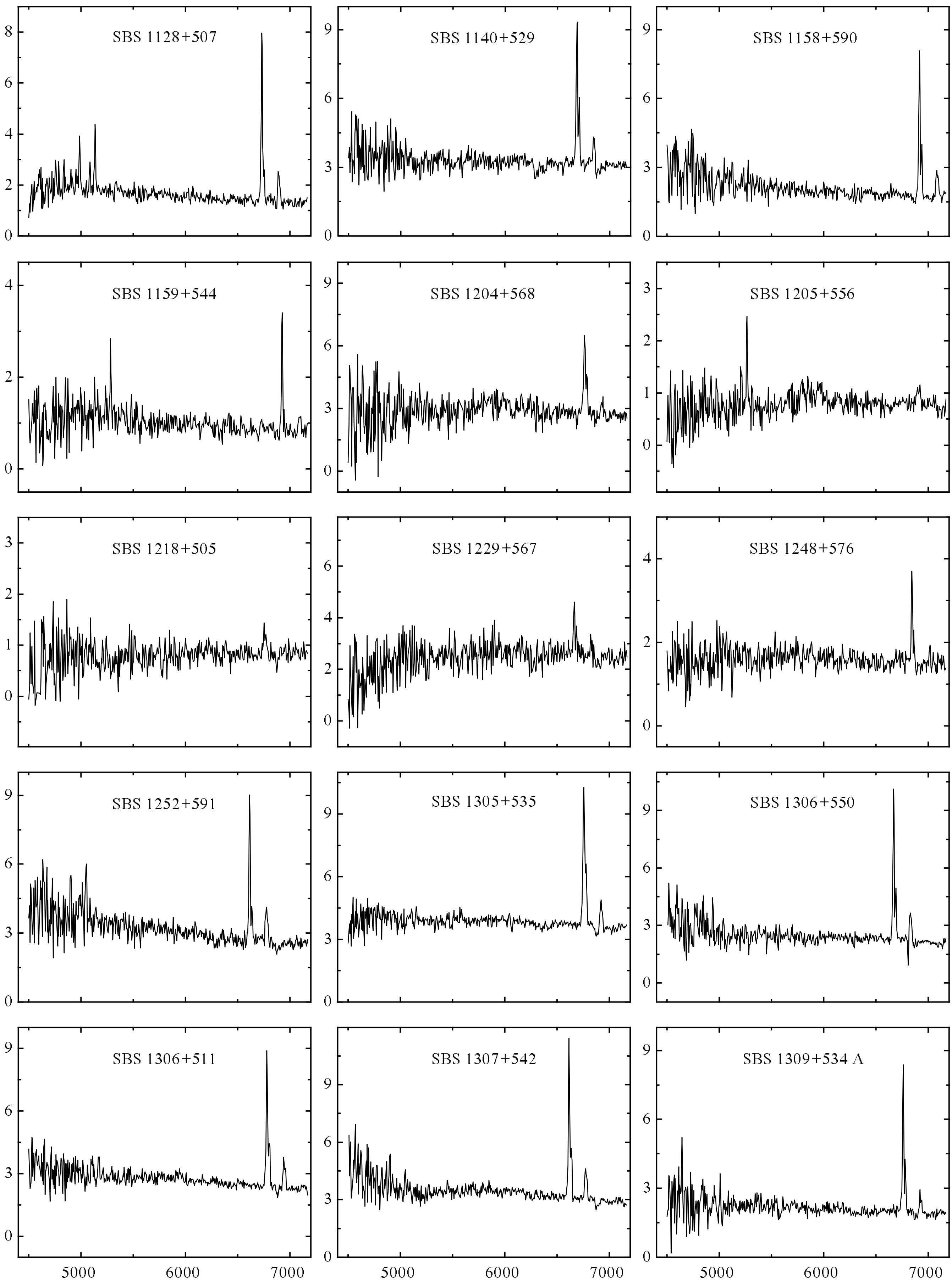

SBS 1128+507
SBS 1140+529
SBS 1158+590
SBS 1159+544
SBS 1204+568
SBS 1205+556
SBS 1218+505
SBS 1229+567
SBS 1248+576
SBS 1252+591
SBS 1305+535
SBS 1306+550
SBS 1306+511
SBS 1307+542
SBS 1309+534 A

Fig. 5.

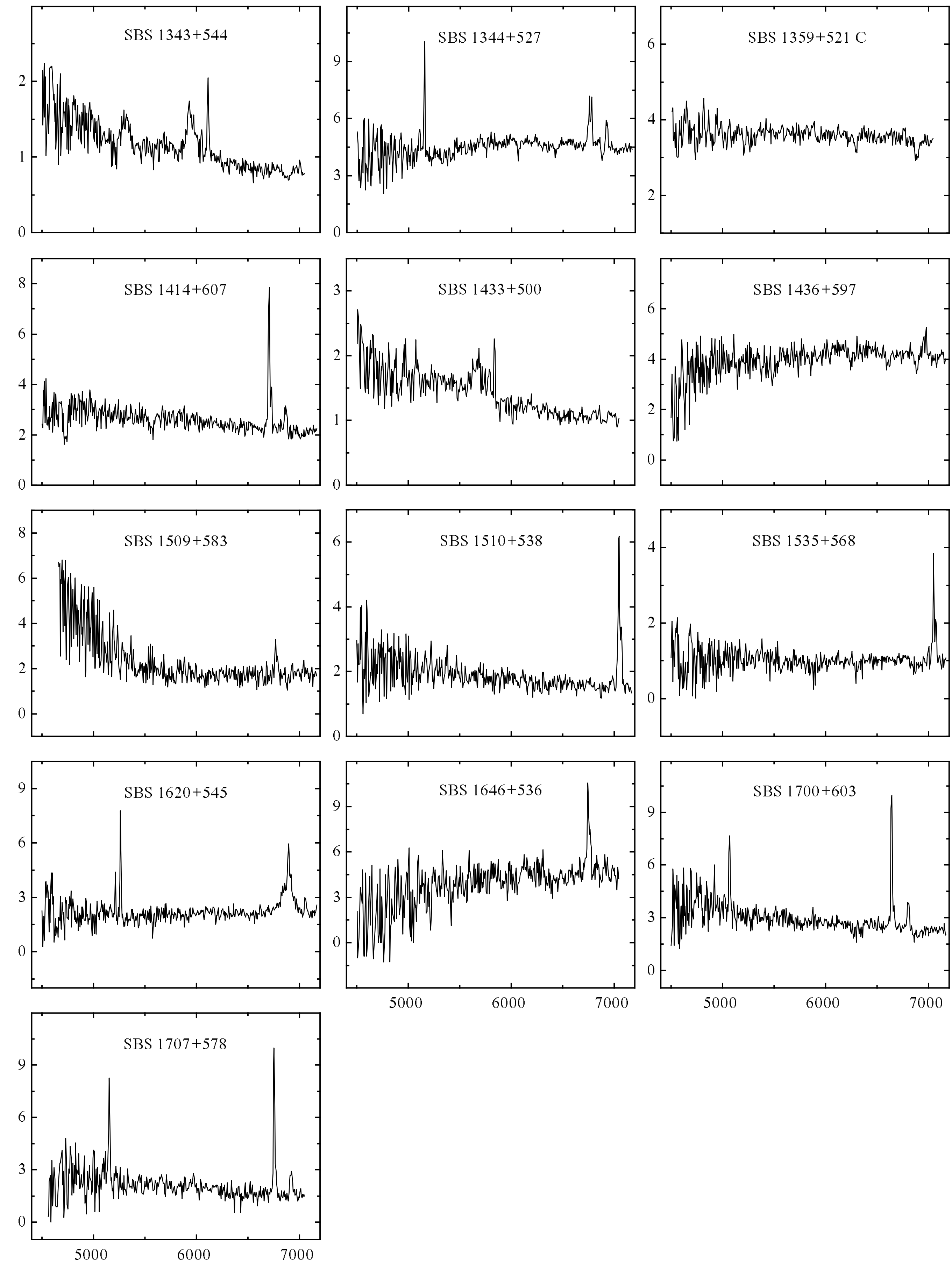

SBS 1343+544
SBS 1344+527
SBS 1359+521 C
SBS 1414+607
SBS 1433+500
SBS 1436+597
SBS 1509+583
SBS 1510+538
SBS 1535+568
SBS 1620+545
SBS 1646+536
SBS 1700+603
SBS 1707+578
5000
6000
7000

Fig. 6.

Table 1. Journal of observations

SBS designation	R.A. 2000	Dec. 2000	m pg	Surv. type	Date of observation	Exp. sec	Other name
0803+565	08 07 33.23	+56 25 33.6	17	dse	13.04.97	2400	
0808+569	08 12 01.06	+56 46 59.1	17	de:	14.04.97	2400	
0824+583	08 28 52.56	+58 12 14.5	16.5	de	06.03.97	1200	
0837+496	08 41 02.59	+49 25 30.9	15.7*	de:	13.03.97	1800	
0858+495	09 01 35.28	+49 18 38.7	16.5	dse	06.03.97	1200	
0859+521	09 03 28.07	+51 59 00.0	15.3*	dse	06.03.97	1200	
0903+558	09 06 56.89	+55 39 06.8	16	sde	09.03.97	1200	
0906+502	09 10 10.01	+50 02 51.0	15.1*	sde	13.03.97	1800	
1005+589A	10 08 40.40	+58 43 56.6	16.5	d2	07.03.97	1200	
1007+536	10 10 43.10	+53 25 14.3	16	de:	12.03.97	1800	
1020+594	10 23 50.03	+59 10 26.6	16	de	13.03.97	1800	
1026+510	10 29 45.46	+50 47 51.1	16.5	ds3e	07.03.97	1800	
1103+506	11 06 21.29	+50 23 18.1	16.5	sd3e	13.03.97	1800	
1124+561	11 27 42.38	+55 55 16.1	16.5	de	13.04.97	2400	
1128+546	11 30 50.57	+54 23 41.9	16	de	09.03.97	1800	
1128+507	11 30 53.18	+50 30 21.8	16	sd3e	13.03.97	1800	
1140+529	11 43 27.33	+52 42 39.8	15.0*	sde	09.03.97	1800	NGC 3829
1158+590	12 00 48.70	+58 47 39.7	16.5	sd2e	09.03.97	1800	
1159+544	12 01 57.75	+54 11 11.3	16	sd2	06.03.97	1200	
1204+568	12 06 43.51	+56 32 36.0	16	d3e	07.03.97	1800	
1205+556	12 08 04.64	+55 24 27.3	16.5	dse:	08.03.97	2400	
1218+505	12 21 24.06	+50 14 13.9	15	de	08.03.97	1800	
1229+567	12 32 08.03	+56 28 16.0	14.6	sde	07.03.97	2100	NGC 4511
1248+576	12 50 50.04	+57 20 40.9	16	de	14.03.97	1800	
1252+591	12 54 22.48	+58 53 41.4	15.0*	de	09.03.97	1800	
1305+535	13 07 41.42	+53 16 35.7	15.1*	se	09.03.97	1800	
1306+550	13 08 33.53	+54 49 54.7	15.2*	de	10.03.97	1800	
1306+511	13 09 01.85	+50 51 32.0	15.5	d3e	09.03.97	1800	
1307+542	13 09 08.75	+53 56 36.1	15.5	d3e	10.03.97	1200	IZw 52
1309+534A	13 11 23.72	+53 11 57.4	15.5*	sde	10.03.97	1800	
1343+544	13 45 16.52	+54 09 25.3	17.5	s1	11.03.97	2400	
					14.04.97	3600	
1344+527	13 46 40.78	+52 28 36.2	15.5	de	10.03.97	1200	
1359+521C	14 01 16.00	+51 52 22.5	15.4	sd2	12.04.96	720	Mkn 1488
					13.04.97	3600	
1414+607	14 15 50.58	+60 28 34.7	16	dse	14.03.97	1800	
1433+500	14 35 10.20	+49 48 14.6	17.5	BSO	15.04.97	3600	CSO 670† ‡
1436+597	14 37 40.53	+59 34 46.7	16.0	d3e	14.03.97	1800	
1509+583	15 10 17.66	+58 10 38.8	16.5	dse	08.03.97	1200	
1510+538	15 12 01.15	+53 38 20.0	16	dse	07.03.97	1200	CG 658†
1535+568	15 36 39.48	+56 41 47.7	16	dse	07.03.97	1800	
1620+545	16 21 45.01	+54 27 23.8	16.5	dse:	12.03.97	1200	
1646+536	16 47 13.54	+53 33 39.9	16.5	de	06.03.97	1200	
					11.04.97	1200	
1700+603	17 01 12.94	+60 15 04.3	15.1*	ds2	09.03.97	1800	
1707+578	17 08 35.32	+57 48 37.1	17	de	15.04.97	2400	

* Magnitudes taken from Zwicky & Herzog 1966, 1968.

† Sanduleak & Pesch 1987.

‡ Bade at al. 1995.

TABLE 2. Results of follow-up spectroscopy

SBS designation	z_0	M pg	c(Hβ)	EW(H$_\beta$) Å	[OIII] 5007	Hαn 6563	[NII] 6584	[SII] 6717+6731	Spectral type
0803+565	0.0268	-18.6				0.00	-0.28		
0808+569	0.0291	-18.8				0.00	-0.39	-0.10	
0824+583	0.0182	-18.2				0.00	-0.26	-0.58	
0837+496	0.0089	-17.5		4.6	0.24	0.46	-0.23	-0.03	
			0.01		0.24	0.45	-0.23	-0.03	
0858+495	0.0281	-19.1				0.00	-0.34	-0.77	
0859+521	0.0294	-20.4		6.2	0.05	0.66	0.16	0.01	
			0.63		0.03	0.45	-0.05	-0.21	
0903+558	0.0376	-20.2		11.6	0.03	0.89	0.37	0.44	
			1.32		-0.01	0.45	-0.07	-0.03	
0906+502	0.0337	-20.9		11.2	-0.19	0.81	0.47	0.32	
			1.07		-0.22	0.45	0.11	-0.06	
1005+589A	0.0307	-19.3		10.5	-0.24	0.68	0.22	0.22	
			0.68		-0.27	0.45	-0.00	-0.02	
1007+536	0.0331	-19.9		7.8	0.17	0.57	0.08	0.33	
			0.36		0.16	0.45	-0.04	0.20	
1020+594	0.0241	-19.2				0.00	-0.24	0.44	
1026+510	0.0255	-18.8		7.4	-0.35	0.47	0.04	-0.03	
			0.04		-0.35	0.45	0.02	-0.04	
1103+506	0.0398	-19.8		4.9	0.71	0.82	0.65	0.46	
			1.11		0.68	0.45	0.28	0.06	
1124+561	0.0182	-18.1		11.7	0.21	0.54	-0.03	0.30	
			0.25		0.20	0.45	0.11	0.22	
1128+546	0.0190	-18.7		7.8	0.23	0.88	0.48	0.41	
			1.28		0.19	0.45	0.05	-0.04	
1128+507	0.0257	-19.3		14.6	0.17	0.64	-0.12	0.07	
			0.55		0.16	0.45	-0.30	-0.13	
1140+529	0.0190	-19.7				0.00	-0.30	-0.46	
1158+590	0.0543	-20.5		9.1	-0.07	0.77	0.26	0.42	
			0.95		-0.10	0.45	-0.06	0.09	
1159+544	0.0554	-21.0		10.3	0.44	0.56	-0.15	-0.01	
			0.32		0.43	0.45	-0.25	-0.12	
1204+568	0.0308	-19.7				0.00	-0.25	-0.43	
1205+556	0.0517	-20.3				0.00	0.30	-0.19	Sy2:
1218+505	0.0286	-20.6				0.00	0.12	-0.44	
1229+567	0.0158	-19.7				0.00	-0.45	-0.24	
1248+576	0.0430	-20.4				0.00	-0.64	-0.64	
1252+591	0.0085	-17.9		10.5	0.29	0.53	-0.02	0.20	
			0.21		0.28	0.45	-0.09	0.13	
1305+535	0.0300	-20.6				0.00	-0.27	-0.58	

Table 2. (continued)

SBS designation	z_0	M pg	c(Hβ)	EW(H$_\beta$) Å	[OIII] 5007	Hαn 6563	[NII] 6584	[SII] 6717+6731	Spectral type
+550	0.0166	-19.2		10.9		0.70	0.36	0.21	
1306+511	0.0334	-20.4		5.9	0.08	0.80	0.36	0.40	
			1.03		0.05	0.45	0.01	0.04	
1307+542	0.0082	-17.3		8.8	-0.22	0.66	0.17	0.20	
			0.63		-0.24	0.45	-0.04	-0.03	
1309+534A	0.0306	-20.2		11.7		0.61	0.21	0.07	
1343+544	0.2212	-22.5							Sy1
1344+527	0.0300	-20.2			0.33	0.00	0.27	0.12	Sy2:
1359+521C	0.0076	-17.3							
1414+607	0.0220	-19.0		4.0		0.95	0.34	0.44	
			1.49			0.45	-0.16	-0.08	
1433+500	0.1660	-21.9							Sy1
1436+597	0.0603	-21.2				0.00	0.16		Sy2:
1509+583	0.0319	-19.3				0.00	-0.18	-0.41	
1510+538	0.0742	-21.7		9.0		-0.19	0.51	0.25	
			0.15			-0.24	0.45	0.20	
1535+568	0.0747	-21.7		8.6		-0.19	0.49	0.32	
			0.11			-0.19	0.45	0.28	
1620+545	0.0516	-20.4		18.9	1.10	1.12	0.99	0.58	Sy2
			1.93		1.04	0.49	0.35	0.35	
1646+536	0.0282	-19.1				0.00	-0.20	0.07	
1700+603	0.0129	-18.9		9.5	0.45	0.66	0.20	0.20	
			0.63		0.43	0.45	-0.01	-0.01	
1707+578	0.0297	-18.8		16.8	0.52	0.60	-0.16	0.18	
			0.45		0.51	0.45	-0.31	0.02	